iCity: A taxonomy of urban analytics and transportation tools

Application & Visualization

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At the Visual Analytics Lab for the iCity project we are developing decision support tools combining social media and mobile data with GIS, demographic, socio-economic and transit data.

Image: iCity Visualization; ESRI cityengine, Betaville, Carl Skelton, Marcus Gordon, Carnevalle, Manpreet Juneja
What is a taxonomy?

A Taxonomy defines the ‘laws of arrangement and division’, a systematic arrangement of objects or concepts showing the relations between them.

Example: The system of arrangement of books in a library

A taxonomy provides researchers with a common language with which to categorize and review existing systems, classify new ones and address gaps towards further development.

(Price, et al., 1993).
Research approach & process

- Literature Review / taxonomy
- Comparative Methodology in Urban Transportation software applications, tools and methods
- Expert Interviews

Image: Design Process, iCity process phases, Jeremy Bowes, Manpreet Juneja
Comparative Methodology of Applications & Toolsets

What are the applications and toolsets currently being used to serve groups of urban users and designers in the urban design and transportation areas?

What do visualization tools provide?

What could be improved?

How could this information be used to create a user-centred taxonomy to support urban transport design and decision making?
Comparative Methodology of Applications & Toolsets

• survey of the application landscape to understand the types of software, and toolsets that exist and the functions already being served.

Use Domains: Software Application Categories

User Stories & Narratives
Navigation, Route Mapping, User Generated Data, Social Media Use

Urban Design & Built Environment
Neighborhood Planning, Complete Streets

Land Use
Agent-based Micro-simulation

Transportation
Traffic Movement, Parking Management

Entertainment & Games
Interactive & Location Based Games, Mixed Reality

Mapping
Cartography, Geo-Visualization

Data Analysis
Intelligent Predictive Analysis, Simulation

Infrastructure Management
Signal & Transit Operations, Sustainability, Resilient Cities

Image: Comparative Methodology, iCity process phases, Manpreet Juneja, Marcus Gordon, Jeremy Bowes
Comparative Analysis of Software

<table>
<thead>
<tr>
<th>Type of Urban System Application</th>
<th>Technology / Description / application</th>
<th>User Type</th>
<th>Tasks (High Level)</th>
<th>Engagement Level</th>
<th>Interaction (Low Level)</th>
<th>Data Visualization</th>
<th>Data Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built environment, geodata, multi-player urban planning</td>
<td>Betaville HTML/ WebGL Three.js, PostgreSQL and PostGIS</td>
<td>designer, planners, architects, technicians</td>
<td>modelling, navigation, visualization, search / exploration, analysis (geometrical), simulation, comment / query</td>
<td>expose (viewing), involve (interacting), analyze (finding trends), synthesis (testing hypothesis)</td>
<td>orbit, walk/ fly-through, pan, scroll, zoom, filter, pivot, linking, select, annotate, transform</td>
<td>3D Bar charts, 3D Pie chart, 3D scatter plot, geo-data</td>
<td>nominal, ordinal, text, geo-spatial, periodic, dynamic, geometry</td>
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<tr>
<td>Qualitative and quantitative Data Exploration and analysis and presentation Tool</td>
<td>StoryFacets HTML, Javascript, D3 framework, Meteor, MongoDB</td>
<td>technicains, transportation engineers, citizens, Business analysts</td>
<td>dataset/media asset navigation, dataset visualization, dataset history and analysis history visualization, decision</td>
<td>expose (consuming, learning and viewing) involve (interacting), analyze (finding trends)</td>
<td>zooming inset, brushing and linking, scrolling, panning, filter, pivot, compare</td>
<td>bar chart, pie chart, gather plot, mark up language</td>
<td>categorical, ordinal, interval, provenance, audio, video, text, image</td>
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<tr>
<td>Transport, land use, demographics</td>
<td>ILUTE (configuration XTMF, ILUTE is a plugin)</td>
<td>planners, researchers</td>
<td>land use scenario forecasting (yearly currently) (aim is to continuous simulation for multi years)</td>
<td>planner: interact, test hypothesis researcher: model development or sub model development</td>
<td>drug and drop, node based processing</td>
<td>(binary matrix) binary format (mtx) files, Excel (tabular data), csv data</td>
<td>relationships, all facets, census transportation network (information about business characteristics, formoological: based on model for e.g. marriage rate, birth rate, etc)</td>
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</table>

This survey aided in aggregating **User Types, Use Domains, User Tasks,** and the **type of Data** being used for Urban Transportation applications, and we recorded the information into a large spreadsheet database.
"Compara"

The VAL research assistants Marcus Gordon, Davidson Zheng and Michael Carnevale, created a first iteration of a web based prototype. This allowed for the dataset modelled from the master spreadsheet, to be explored interactively.
Taxonomy Sketch showing essential aspects of visualizations

Most approaches to establishing a visualization taxonomy essentially fell into three areas: **User Task**, **Level of Interaction** or Engagement and **Data Type**. (Mahyar, et al., 2015)
Thus, the challenge is to ensure diverse groups of users have 
**appropriate levels of accessibility** to data in usable forms, 
which in turn requires understanding the **visualization needs** of 
multiple user groups.

A well-developed taxonomy of visualization types can help designers 
understand which visualization techniques (or combinations of them) best serve 
the goals and needs of user and stakeholder groups (Chengzhi, 2013).
Use Case survey

**User Type**
Gender, Age, Nationality, Occupation

**Application Scenario**
Description of Tasks
Preconditions
Technology
Software, Environments and Frameworks
Assets
Formats, Functions
Task interaction
How are you using this software/tool?

**Data Visualization**
What is the visualization functionality of this software/tool?

**Improvements**
How could the software/tool be changed to support the required tasks?

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**URBAN INFORMATICS USE CASE PROFILE**

**User Type**
Gender: Male  Age: 56  Nationality: Canadian  Occupation: Architectural technician

Manpreet Juneja, Carl Skelton, Jeremy Bowes

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**Application Scenario**

Laz is a senior architectural technician working for city planning. His area of expertise is reviewing rezoning applications and new development projects.

He needs to provide two documents of his findings:
- an explanatory presentation (slide show) for an upcoming community meeting,
- a formal record of the application’s parking implications, context, applicable regulations,
- recommended ruling based on the above items.

**Description of Tasks**

- Exploration of geodata & 3D model of existing conditions,
- record of parking inventory in defined area,
- calculation of requirements with/without proposed changes,
- export of tabular data and graphics,
- preparation of formal document and slide presentation for ruling recommendation - decision support/justification/communication with decision-makers and stakeholders.

**Preconditions**
Knowledge of local study area, accessibility to platform, understanding of interface & functionality, availability of peak parking data, both on-street and private etc.

**Technology**

Software: ArcGIS, CityEngine, Insight3.


**Assets**

Formats: online SHP, CSV, XLS, JSON, daily, daily files.

Functions: 3D: For charts, Geo—Data, Geo chart, interactive digital maps with on/off information layer switching, call-out boxes.

**Task Interaction**

How are you using this software/tool?

- Click, Walk/ Fly-through, pan, scroll, zoom, select, annotate, measure, (annotate measurement?),
- zooming in/out, scrolling, panning, capture, microsimulation etc.

**Data Visualization**

What is the visualization functionality of this software/tool?

Uses technological interface to visualize street segment, with displayed data of parking information per location as statistical comparison.

Capture of generated scenario data in a form for presentation. Access of demographic community data to project potential local patrons to future establishments. Interface to select, analyze, and prepare a visual summary of queried data on parking locations.

**Improvements**

How could the software/tool be changed to support the required tasks?

- Real-time 3D infographics superimposed, 2D map, highlighted statistical charts, prep of visual narrative.

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Image: Use Case Surveys, iCity process phases, Manpreet Juneja, Carl Skelton, Jeremy Bowes
Use Case Mapping

Selected Integrated Use Domain Example
Design Charrette

Test and Refine Taxonomy Sketch Concepts and to Establish priorities to build interface prototypes
Research approach & process

• User-Centred Taxonomy for Urban Transportation Applications
• Template prototype

Materialize and prototype

• Design a taxonomy prototype that qualifies types of users, use domains and detailed context of use, integrates user engagement goals with the essential components of visualization, and highlights the end user and their intended interactions with the visualization.
User-centred Taxonomy for Urban Transportation application visualization

User engagement goals

Use Domains
- Traffic
- Transit
- Roadways
- Design
- Cartography
- Operations
- Urban Design
- Urban Planning
- Policy and Regulation
- Land Use
- Services
- Maintenance
- Capital Planning

Users
- Researcher
- Hardware/Software vendor
- Designer, Planner, Operator
- Decision-maker/proponent
- Politician
- Real-estate developer
- Advocate
- City staff
- Surveyor
- Statistician
- Engineer
- Business user
- Citizen/resident
- Home-owner
- Tenant
- Guest/tourist
- Driver
- Pedestrian
- Cyclist

Context for User Engagement
- Engagements
  - (High Level Engagement)
    - Decide (Deriving decisions)
    - Synthesize (Testing hypothesis)
    - Analyze (Finding trends)
    - Author (Adding content)
    - Involve (Interacting)
    - Expose (viewing)
- Tasks
  - share, distribute, publish
  - derive, simulate,
  - explore, compare, encode, infer, survey, etc.
  - comment, query, upload
  - navigation, way finding, search, locate, games, etc
  - information display

Visualization components

Data Type
- Abstract (a) / Spatial (s) (Input<-->Output)
  - a<-->s
  - a<-->a
  - s<-->a
  - s<-->s

Data (Da/Ds)
- Da<-->Ds
- Da<-->Da
- Ds<-->Ds
- Ds<-->Da

Visual (Va/Vs)
- Va<-->Ds
- Va<-->Da
- Vs<-->Ds
- Vs<-->Da

Navigation (Na/Ns)
- Na<-->Ds
- Na<-->Da
- Ns<-->Ds
- Ns<-->Da

Context for Interactive Controls in Visualizations

(High Level)
- Representation Intent
- Interaction Intent
- Select, Explore, Reconfigure, Encode, Elaborate, Filter, Connect, Simulation, Authoring, Modelling

Representation Technique
- Charts, Graphs, Networks, Treemaps, Parallel Coordinates

Interaction Technique
- Selection, Brushing, Dynamic query, Pan/Zoom,...

Feedback

Image: Based on Pike (2009), Mahyar (2015) and Sorger (2015), iCity process phases, Taxonomy, iCity Team
Testing the Taxonomy template

Use Case – the architectural technician
This use case from our user group research depicts the technician working on the review of a rezoning proposition for a new building. Two main tasks occupy this technician’s work on such a project:

1. the exploration of datasets, and
2. analysis of land use, parking resources, and demographics.

Using our template taxonomy chart, we can first classify our user engagement goals with the technician as user and urban planning as use domain.

![Use Domain of the Architectural Technician tasks]

Image: Based on Pike (2009), Mahyar (2015) and Sorger (2015), iCity process phases, Taxonomy, iCity Team
Use Case – the architectural technician

- The technician is required to perform quantitative data exploration and analysis in order to determine if the building application in question would create any issues with parking lot spaces being overwhelmed by new users.

- The taxonomy’s user engagement context would classify this technicians’ activity as analysis and the finding of trends, (to unravel the patterns that will help the technician to generate decision support data for synthesis.)

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<th>Context for User Engagement</th>
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<td>Engagements</td>
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<td>Synthesizing (Testing hypothesis)</td>
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<td>Analyzing (Finding trends)</td>
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<td>Authoring (Adding content)</td>
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<td>Involving (Interacting)</td>
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<td>Exposing (Viewing)</td>
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Architectural technician’s User Engagement

Image: Based on Pike (2009), Mahyar (2015) and Sorger (2015), iCity process phases, Taxonomy, iCity Team
Use Case – the architectural technician

- The technician’s work in this use case involves **geospatial data**, (GIS) web, and graphic frameworks, making use of (a) abstract and (b) spatial data types.

- In this example, these include sheets, tables, maps and charts - both as input source & output target domains.

- Quantitative data sets of a neighborhood population, can be displayed as a table of data or a 3D geospatial plot to compare or simulate.

Suggested Visual representation options are added here
**USER CENTRED TAXONOMY**

*Use Case – the architectural technician*

## User Engagement Goals

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### (High Level Engagement)

- Decide (Deriving decisions)
- Synthesize (Testing hypothesis)
- Analyze (Finding Trends)
- Author (Adding content)
- Involve (Interacting)
- Expose (Viewing)

### (Low Level Engagement)

- Share, distribute, publish
- Derive, simulate,
- Explore, compare,
- Encoded, infer,
- Search, locate,
- Information display

## Visualization Components

### Data Type

- **Abstract (a) / Spatial (s)** (Input<->Output)
  - a<->s
  - a<->a
  - s<->a
  - s<->s

<table>
<thead>
<tr>
<th>Data (Da/Ds)</th>
<th>Visual (Va/Vs)</th>
<th>Navigation (Na/Ns)</th>
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### Context for Interactive Controls in Visualizations

- **Representation Intent**
  - Defer, Differentiate, Identify, Show, Compare
  - Select, Explore, Reconfigure, Encode, Elaborate, Filter
  - Connect, Simulation, Authoring, Modelling

- **Representation Technique**
  - Charts, Graphs, Maps, Networks, Tables, Room maps, Parallel Coordinates

- **Interaction Technique**
  - Selection, Brushing, Dynamic query, Pan/Zoom,....

*Image: Based on Pike (2009), Mahyar (2015) and Sorger (2015), iCity process phases, Taxonomy, iCity Team*
The visualization landscape project (VIZLAND)

The ability to query keywords associated to these visualizations is to give the user quick access to matching keywords that relate to the visuals. This is done by the user typically matching functions that are prominent in selected visualizations.

Image Data Source: VIZLAND development By Marcus Gordon, VAL, Severino Ribecca, Data Visualization Catalogue
Next steps: Research process

- Creating the dashboard prototype
- COMPARA derives intelligence on toolsets and software that are mapped to their respective User Group and Domain specifications.
- VIZLAND (the Visualization LANDscape) provides the optimum representation techniques most suited for a particular use case.

Image: iCity Visualization; Jeremy Bowes, Manpreet Juneja
USER CENTRED TAXONOMY FOR URBAN TRANSPORTATION APPLICATIONS

User engagement goals

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Context for User Engagement

Engagements

(High Level Engagement)

Decide (Deriving decisions) share, distribute, publish
Synthesize (Testing hypothesis) derive, simulate,
Analyze (Finding Trends) explore, compare, encode, infer, survey, etc.
Author (Adding content) comment, query, upload
Involve (Interacting) navigation, way finding, search, locate, games, etc
Expose (viewing) information display

(Low Level Engagement)

Visualization components

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Context for Interactive Controls in Visualizations

Representation Intent
Represent Differentiate, Identify, Show outliers, Compare
Interaction Intent
Select, Explore, Reconfigure, Encode, Elaborate, Filter, Connect, Simulation, Authoring, Modelling
Representation Technique
Charts, Graphs, Networks, Treemaps, Parallel Coordinates
Interaction Technique
Selection, Brushing, Dynamic query, Pan/Zoom, ...
COMPARA: an intuitive interactive and searchable index that visualizes the attributes of software from a wide-range of applications and technologies.

VIZLAND: aspires to map a multitude of libraries that define data visualization types, their functions, their representational form, shapes, analytic capabilities, and descriptions, and making them query-able through a web interface.

Image: iCity Visualization Templates; Jeremy Bowes, Manpreet Juneja
Drawing from both Ontology & Taxonomy studies in iCity, the Dashboard will incorporate elements that produces the most viable visualization recommendation for applications hosted within the platform.
WHY DASHBOARD? - Contributions

**Engagement**
Allows for Civic Engagement in the context of the City and its many affordances.

**Statistics**
The City stats creates rationale as well as proves plans for functional urban planning & management

**Planning & decision support**
Urban Planning based on insights that are crowd-sourced from residents of the City.
These findings focused our approach to establishing a visualization taxonomy focused on three areas: **User Task**, **Level of Interaction** or Engagement, and **Data Type**, and the detailed classification of interactive elements based on user tested needs for **spatial and non-spatial data types** within our research groups.

The **taxonomy** prototype outlines a key framework to create a series of **interactive dashboards** that provide the integration of these functional user elements to provide visualization support for a variety of users.
Implementing the Taxonomy framework into the Dashboard Use Case – the the traffic operator

User Engagement goals

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Context for User Engagement

- Decide (Deriving decisions)
- Synthesize (Testing hypothesis)
- Analyze (Finding Trends)
- Author (Adding content)
- Involve (Interacting)
- Expose (viewing)

User Engagement

- Share, distribute, publish
- Derive, simulate
- Explore, compare, encode, infer, survey, etc.
- Comment, query, upload
- Navigation, way finding, search, locate, games, etc
- Information display

Visualization Components

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Dashboard

Image: iCity Dashboard Development; Lee Balki, Jeremy Bowes
Music video that takes aim at TTC being investigated by police https://www.cp24.com/news/music-video-that-takes-aim-at-ttc-being-investigated-by-police-1.3950474 ...
The image depicts a user interface for an application called iCity Dashboard Development. The interface includes options for selecting user types, domains, and settings. The diagram shows the process of user engagement and task distribution, with categories like Decide, Synthesize, Author, Involve, and Expose. The context for user engagement is represented with tasks such as share, distribute, publish, derive, simulate, explore, compare, encode, infer, survey, comment, query, upload, navigation, way finding, search, locate, games, etc. The interface highlights the Analyze (Finding Trends) button, indicating its significance in the user engagement process.
Date Range further specifies data to be filtered.
Applications: Preset views of datasets derived from present Use case scenario.

Use Case Scenario: A combination of User Type, Use Domain & Date Range (selected above) along with a range of Engagement Goals & Tasks, based on priority.
Preset views make use of the taxonomy framework (VIZLAND component) to choose the representation technique for a given dataset.

Image: iCity Dashboard Development; Lee Balki, Jeremy Bowes
Presets & views & make & use & of & the & taxonomy & framework (VIZLAND component) to choose the representation technique for a given dataset.

**Data Type**

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**Context for Interactive Controls in Visualizations**

- Representation Intent
  - Depict, Differentiate, Identify, Show outliers, Compare
- Interaction Intent
  - Select, Explore, Reconfigure, Encode, Elaborate, Filter.
  - Connect, Simulation, Authoring, Modelling
- Representation Technique
  - Charts, Graphs, Networks, Treemaps, Parallel Coordinates
- Interaction Technique
  - Selection, Brushing, Dynamic query, Pan/Zoom.

Image: iCity Dashboard Development; Lee Balki, Jeremy Bowes
Thank you
Questions?

Professor Jeremy Bowes
Visual Analytics Lab, OCAD University
Jbowes@faculty.ocadu.ca

Acknowledgements
The authors gratefully acknowledge the support of OCAD University and the Visual Analytics Lab, Canada Foundation for Innovation, the Ontario Ministry of Research & Innovation through the ORF-RE program for the iCity Urban Informatics for Sustainable Metropolitan Growth research consortium; IBM Canada and MITACS Elevate for support of post-doctoral research; NSERC Canada CreateDAV, and Esri Canada and MITACS for support of graduate graduate internships.
Bibliography


Chengzhi, Q., Chenghu, Z. & Tao, P. (2003), **Taxonomy of Visualization Techniques and Systems**—Concerns between Users and Developers are Different, Asia GIS Conference 2003.


Bibliography


